Capillary refill time and cardiac output in children undergoing cardiac catheterization*

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Objective: **Many pediatric healthcare providers believe that capillary refill time is a measure of perfusion and cardiac output in children. Despite its widespread use, there are no studies examining the relationship of capillary refill time to cardiac output in noncritically ill children. This study examined the inter-rater reliability of capillary refill time and its relationship to hemoglobin and with cardiac output in pediatric patients undergoing cardiac catheterization.**

Design: **Prospective observational study.**

Setting: **Tertiary care pediatric hospital.**

Patients: **A total of 58 children, ages 0.3–17 yrs, with congenital heart disease undergoing cardiac catheterization.**

Interventions: **Two clinicians performed two measurements of capillary refill time in a standardized fashion on 58 children undergoing cardiac catheterization. Cardiac output was determined by the Fick method within 15 mins of the first assessment of capillary refill time (time 1).**

Measurements and Main Results: **Capillary refill time and cardiac output measurements were obtained in 44 children, and 108 paired measurements of capillary refill time were obtained to assess inter-rater reliability. The mean capillary refill time was 1.2 secs (±0.5 secs), and the mean cardiac output was 3.6 L/min/m^2 (2.2–5.7 L/min/m^2). The inter-rater intraclass correlation coefficient was 0.12 (time 1) (95% confidence interval −0.15 to +0.37) and was 0.32 (95% confidence interval 0.058–0.54) at the end of the catheterization (time 2). A significant association was noted between average capillary refill time at time 1 and hemoglobin, with higher hemoglobin correlating with longer capillary refill time ($p = .015$). There was no significant correlation between the average capillary refill time taken at the time of cardiac output measurement (time 1) and measured cardiac output ($r = .331$, 95% confidence interval for r, .066–.552).**

Conclusions: **We found that the inter-rater reliability of capillary refill time was poor and variable under controlled conditions and capillary refill time was not correlated with cardiac output in anesthetized nonacutely ill pediatric patients undergoing cardiac catheterization. Caution should be used in inferring cardiac output from capillary refill time measurements alone. (Pediatr Crit Care Med 2012; 13:136–140)**

Key Words: capillary refill time; cardiac output; hemoglobin; inter-rater reliability; pediatrics

Capillary refill time (CRT) is the time required for return of normal color after application of blanching pressure to a distal capillary bed (1). Although CRT is no longer considered useful in adult patients (2), CRT is widely taught as a method of assessing hydration and circulatory status in children (3–5). Many pediatric critical care and emergency medicine healthcare providers believe that CRT is a measure of cardiac output and perfusion (6).

***See also p. 210.**

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Despite the widespread use of CRT in pediatrics, there is only one study examining its relationship to cardiac output. Tibby et al (7) examined the relationship between CRT and hemodynamic parameters in 55 critically ill pediatric patients in the intensive care unit. Results from this study showed CRT correlated poorly with all hemodynamic variables and that only extremely prolonged CRT (≥6 secs) was associated with low stroke volume index (7). There are no studies examining the relationship of CRT and cardiac output in noncritically ill children.

Our prospective observational study examined the inter-rater reliability of CRT when performed under controlled conditions, its relationship to hemoglobin, and the correlation of CRT with cardiac output in nonacutely ill pediatric patients undergoing elective cardiac catheterization.

METHODS

Ethics approval was obtained from the Children's Hospital of Eastern Ontario Research Ethics Board in Ottawa, Canada, and written informed consent for participation was obtained for all participants.

All patients between 2 wks and 17 yrs of age undergoing elective cardiac catheterization at Children's Hospital of Eastern Ontario were approached for study enrollment. Exclusion criteria included non-English- or non-French-speaking families and lack of consent from parents or the legal guardian. Patients were also excluded from the study if they required inotropes or vasoactive medications during cardiac catheterization.

The same two clinicians (a critical care nurse and a pediatric cardiologist) were formally trained in the assessment of CRT. CRT was performed in a standard way by applying firm pressure on the palmer surface of the patient's distal finger or foot for 5 secs on the upper or lower limb, avoiding venous refill by raising the limb slightly above the level of the heart (1, 3, 7–10). In a given patient, CRT was always performed in the same limb by both clinicians. CRT was performed during cardiac catheterization under general anesthesia. The anesthetic agents used during each case were similar and included a combination of narcotics (fentanyl, remifentanyl, and morphine), a muscle relaxant (rocuronium), and inhalational agents (sevoflurane, isoflurane). The procedures were performed in a well-lit catheterization laboratory at standard ambient temperature (21°C). None of the patients required being placed under overhead warmers to maintain their temperature at >36°C. The time until restoration of normal color was recorded using the same stopwatch once the clinician's finger was released, with normal CRT defined as ≤2 secs in pediatric patients (3–5, 8, 9, 11).

The first CRT measurement (time 1) was performed during cardiac catheterization within 15 mins of determining cardiac output by the Fick method using measured oxygen consumption (12) via a polarographic machine (MRM-2, Waters Instruments, Rochester, MN). The second CRT measurement (time 2) was performed at the end of the catheterization. Clinicians were blinded to each other's assessments. The CRT at time 1 was recorded separately by the clinicians before the measurement of cardiac output. The measurement of cardiac output was calculated by the pediatric cardiologist after the CRT assessment at time 2. Hemoglobin levels were recorded for all patients in whom they were available within 48 hrs of catheterization.

Statistical analysis was conducted using SPSS 18 (SPSS, Chicago, IL). All p values were two-sided and were considered statistically significant at the .05 level. The CRT and cardiac output measurements were summarized using means and standard deviations. The inter-rater reliability of CRT was measured by the intraclass correlation coefficient (ICC) and paired sample t test. An ICC of 0.81–0.99 was interpreted as almost perfect agreement, 0.61–0.80 as substantial agreement, 0.41–0.60 as moderate agreement, 0.21–0.40 as fair agreement, and 0.01–0.20 as slight agreement. The correlations between CRT and cardiac output, between CRT and pulse oximetry, and between CRT and hemoglobin were measured by Pearson's correlation coefficient. A logistic regression model was used to determine the effect of age on the relationship between CRT and cardiac output.

RESULTS

Over a total of 30 months, beginning November 22, 2005, 63 patients were eligible to be studied. None of the patients were inpatients during the time of catheterization and were considered to be of usual health before the procedure. All of the catheterizations were considered to be elective and nonemergent. Three families of eligible patients refused consent, and in one patient, there was a language barrier.

Table 1. Patient variables and values for oxygen saturation, hemoglobin, average capillary refill time, and cardiac output

Variable	Minimum	Maximum	Median	Standard Deviation
Age (yrs)	0.3	17.0	6.6	5.3
Weight (kg)	5.1	79.0	26.7	20.6
Oxygen saturation[a]	80	100	98.5	5.5
Hemoglobin[a] (g/L)	102	182	134	17.3
Average capillary refill time between two clinicians (time 1)[b] (secs)	0.6	3.0	1.1	0.5
Average capillary refill time between two clinicians (time 2)[c] (secs)	0.6	3.0	1.2	0.6
Cardiac output (L/min/m^2)	2.2	5.7	3.3	1.0

[a]Hemoglobin and saturation values available for 53 and 52 patients, respectively, due to incomplete data sets; [b]capillary refill time assessed at time of cardiac output measurement; [c]capillary refill time assessed at the end of the cardiac catheterization.

Fifty-nine children and their families agreed to participate in the study (Table 1). Of the participants, 56% were male and 44% female, ranging in age from 0.3 to 17 yrs. Of the 59 patients, 25% had single-ventricle physiology (Table 2). In addition, 62% of patients underwent an interventional catheterization, and 38% of patients had catheterizations for diagnostic purposes. One child died during catheterization before CRT and cardiac output measurement. Four patients were excluded during data analysis for incomplete data sets (Fig. 1). One hundred eight paired measurements of CRT were obtained in 54 children (31 male, 23 female), with a mean age of 6.6 yrs (0.3–17 yrs). Cardiac output was determined in 44 children. Cardiac output was not measured in 11 patients as there was no indication for either the left- or right-sided catheterization necessary to obtain the hemodynamic information necessary to determine cardiac output.

The range of CRTs recorded by the two clinicians at time 1 (within 15 mins of determining cardiac output) was 0.5–4.4 secs, and at time 2 (the end of cardiac catheterization) was 0.3–4.3 secs. The mean CRT from the two clinicians at time 1 was 1.2 ± 0.5 secs, and the mean CRT at time 2 from the two clinicians was 1.4 ± 0.6 secs (Fig. 2). The mean paired difference in CRT between the two clinicians at time 1 was 0.233 secs (95% confidence interval (CI) −0.022 to +0.488, $p = .073$), and that at time 2 was 0.22 secs (95% CI −0.031 to +0.471, $p = .084$). The inter-rater ICC at time 1 was 0.12 (95% CI −0.15 to +0.37), and that at time 2 was 0.32 (95% CI 0.058–0.54). The mean cardiac output was 3.6 L/min/m^2 (2.2–5.7 L/min/m^2). There was no significant correlation between the average CRT taken by the two clinicians at time 1 and cardiac output (Pearson correlation coefficient −0.161, 95% CI −0.434 to +0.139) (Fig. 3).

Table 2. Diagnosis of patients undergoing cardiac catheterization

Diagnosis	Number of Patients
Atrial septal defect	8
Patent ductus arteriosus	7
Status post repair of tetralogy of Fallot	6
Tricuspid atresia	2
Aortic valve stenosis	2
Status post repair (Ross procedure)	1
Preoperative evaluation	1
Hypertrophic cardiomyopathy	1
Double outlet right ventricle	5
Status post repair of double outlet right ventricle	1
Preoperative evaluation	4
Pulmonary valve stenosis	4
Status post repair of atrioventricular septal defect	3
Status post repair of transposition of great arteries	6
Coartaction	2
Double inlet right ventricle	1
Pulmonary hypertension	1
Status post Fontan procedure	7
Original Diagnosis of tricuspid atresia	1
Original diagnosis of double inlet left ventricle	1
Original diagnosis of double outlet left ventricle	1
Original diagnosis of unbalanced atrioventricular septal defect and dominant left ventricle	1
Original diagnosis of double outlet right ventricle and transposition of great arteries	1
Original diagnosis of double inlet right ventricle	2
Pulmonary atresia	3
Kabuki syndrome	1

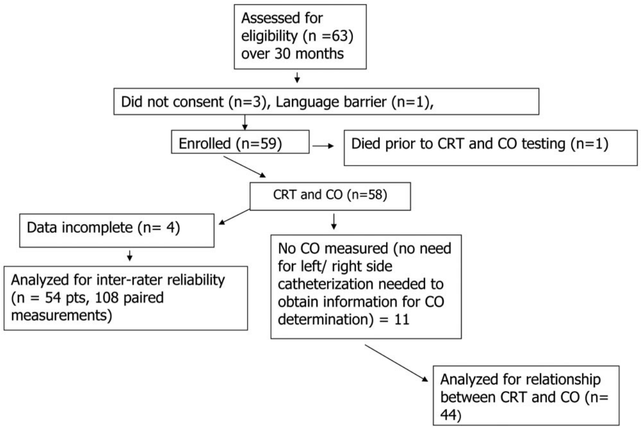

Figure 1. Consort diagram: patient recruitment and flow diagram. *CRT*, capillary refill time; *CO*, cardiac output.

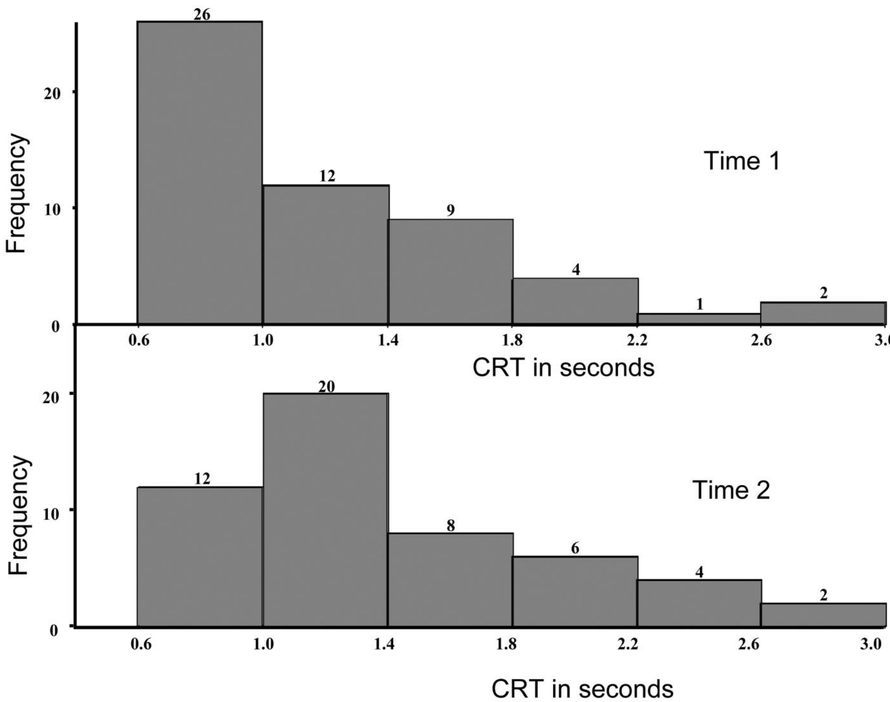

Figure 2. Histogram: average capillary refill times (*CRTs*) between two clinicians at time 1 and time 2.

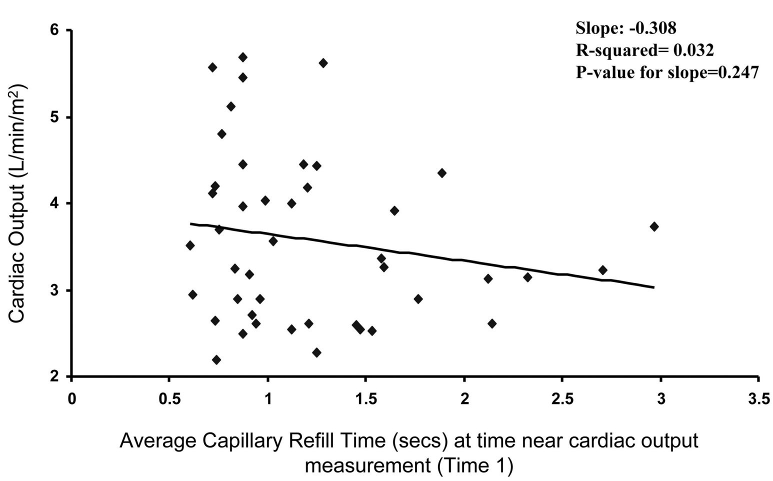

Figure 3. Relationship between cardiac output and average capillary refill time (time 1). Capillary refill time (time 1) was performed within 15 mins of the measurement of cardiac output.

Hemoglobin values ranged between 102 and 182 g/L with a mean of 136.2 ± 17.3 g/L. A significant association was noted between the mean CRT at time 1 and hemoglobin levels (Pearson correlation coefficient 0.331, 95% CI 0.066–0.552), with higher hemoglobin levels correlating with longer CRT (p = .015, Fig. 4). However, after controlling for hemoglobin, there was no significant correlation between cardiac output and CRT (Pearson correlation coefficient −0.233, p = .39). The mean oxygen saturation was 96.2% ± 5.5% (80% to 100%). The correlation between the mean CRT taken by two clinicians at time 1 and oxygen saturation was not significant (Pearson correlation coefficient −0.143, 95% CI −0.400 to +0.135) (Fig. 5).

DISCUSSION

This prospective cohort study examined the inter-rater reliability of CRT as a clinical test under controlled circumstances, its relationship to hemoglobin, and the correlation of CRT with cardiac output in non-acutely ill pediatric patients undergoing elective cardiac catheterization.

CRT is widely taught in pediatrics as a simple and quick test of circulatory status (4, 5). Both American and Canadian pediatric advanced life support courses suggest that prolonged CRT (>2 secs) may be caused by shock, a rising fever, cold ambient temperature, or relative hypovolemia (4, 5). Pediatric sepsis management guidelines also include prolonged CRT as part of the criteria for diagnosing cold shock in children (13, 14). In addition, many pediatricians suggest that parents should learn to perform CRT on their children and seek immediate medical attention if the result is abnormal (15).

A few studies have been done examining the inter-rater reliability of CRT as a clinical test. A recent study by Brabrand et al (16) in adult patients cautioned against the use of CRT as the investigators found only moderate agreement for the exact value of CRT and a moderate agreement for normality. Other pediatric studies examining different populations, including healthy newborns to dehydrated children, have reported a fair to moderate inter-observer reliability for CRT (1, 17–19). In our study, we found that the inter-rater reliability was poor (ICC = 0.12) to fair (ICC = 0.32). This suggests that, even under controlled conditions (i.e., patient under general anesthesia, temperature maintained, same cli-

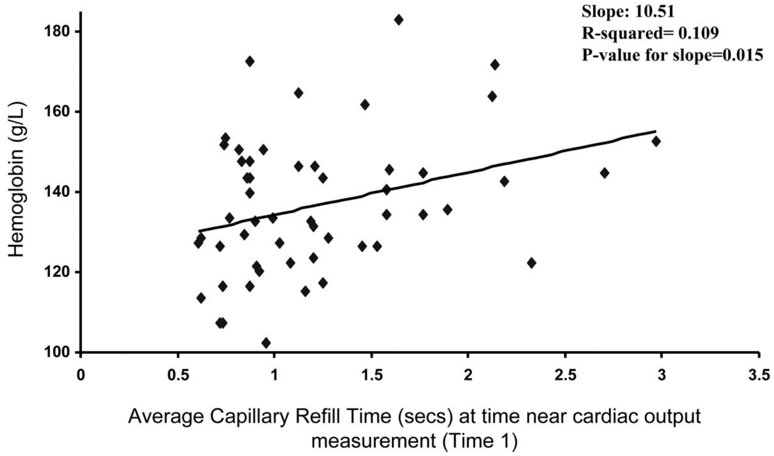

Figure 4. Relationship between hemoglobin values and average capillary refill time (time 1). Capillary refill time (time 1) was performed within 15 mins of the measurement of cardiac output.

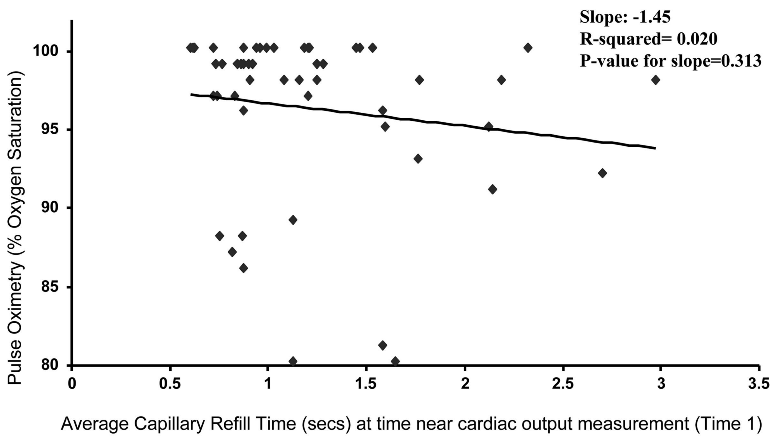

Figure 5. Relationship between pulse oximetry (percent oxygen saturation) values and average capillary refill time (time 1). Capillary refill time (time 1) was performed within 15 mins of the measurement of cardiac output.

nicians performing CRT), the inter-rater reliability of CRT may be quite low.

In 2008, we published a survey describing the use of CRT by healthcare professionals (6). We found that although the majority of survey responders used CRT frequently, there was no consistent response in how they performed and interpreted CRT (6). However, despite the inconsistent performance and interpretation of CRT, a significant percentage of healthcare providers agreed that CRT is a measure of cardiac output in children (6). Given this, we sought to determine the relationship between CRT and cardiac output. In this study, we did not find any correlation between CRT and a wide range of values for cardiac output (2.2–5.7 L/min/m^2) in nonacutely ill pediatric patients undergoing cardiac catheterization. Although CRT was performed in nonacutely ill children, our sample did include abnormal CRTs (>2 secs) and a wide range of cardiac outputs (2.2–5.7 L/min/m^2) that would be considered outside the normal range (i.e., values of <3.5 and >5.5 L/min/m^2) (20), which also did not correlate with CRT. Our results suggest caution in using CRT alone to measure or infer cardiac output in nonacutely ill patients. An important finding in our study is that nonacutely ill anesthetized children often have a normal CRT (<2 secs) despite a low cardiac output. This may be due to anesthesia-induced vasodilation, and we suggest that clinicians be aware that normal CRT in an anesthetized or heavily sedated patient may not necessarily imply that the patient's cardiac output is normal.

To our knowledge, this is the only study examining the relationship between CRT and cardiac output in nonacutely ill children. Other studies have focused on the relationship between CRT and perfusion as a surrogate for the direct measurement of cardiac output. A recent pediatric study showed a very poor correlation between arterial blood flow and CRT in lower extremities, suggesting that CRT is not effective in detecting changes in arterial blood flow (21). Furthermore, a recent review in neonates suggested that peripheral CRT is not a useful assessment of hemodynamic status (22). In addition, a study in neonates by Osborn et al (23) examined the accuracy of CRT in detecting low upper body flow and showed that only prolonged (4 secs) central CRT (i.e., performed on the anterior chest) provided a posttest probability of low superior vena cava flow of 56%. The only other study to examine the relationship between cardiac output and CRT (7) showed that only extremely prolonged CRT (≥6 secs) was associated with low cardiac output in critically ill patients in the pediatric intensive care unit. In contrast to that report (7), our study was done in a group of nonacutely ill pediatric patients under general anesthesia who were considered to be of usual health. Future studies could examine the use of multiple clinical variables used to assess perfusion in combination with CRT to assess their relationship with cardiac output.

Similar to a previous study examining the effects of polycythemia on capillary perfusion in neonates (24), results from our study suggest that high hemoglobin levels are correlated with longer CRT in pediatric patients. Higher levels of hemoglobin likely increase resistance to flow in peripheral capillaries and may affect the interpretation of CRT in polycythemic patients.

There are a few limitations to this study. The first limitation is inherent to performing CRT in clinical practice. There is no precise measurement of "moderate" pressure, and the end point (refilling of the blanched area), even when measured by a stopwatch, can sometimes be difficult to interpret. However, this reflects clinical practice as CRT is performed in a variety of ways in clinical practice without the use of a stopwatch and an exact measurement of moderate pressure (6). Another limitation of this study is that CRT and cardiac output measurements were performed in a narrow group of nonacutely ill patients who were under general anesthesia in a cardiac catheterization laboratory. However, testing of cardiac output by the Fick method is the only widely accepted method of measuring cardiac output and is currently only performed in the catheterization laboratory. Finally, CRT was performed in anesthetized patients during cardiac catheterization to measure cardiac output. Medications administered for general anesthesia can cause changes in systemic vasculature leading to brisk CRTs (<2 secs; see Fig. 2). However, this is still important information as CRT is performed in many patients in clinical practice who may have received sedative or anesthetic agents.

CONCLUSIONS

We found that CRT had poor and variable inter-rater reliability and that there was no correlation between CRT and cardiac output in anesthetized nonacutely ill pediatric patients undergoing cardiac catheterization. This finding may be due to polycythemia, the use of anesthesia during cardiac catheterization, or the absence of patients with significantly low cardiac output in our study. We caution healthcare providers in using CRT alone as a measure of cardiac output.

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